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(54) **Composite preforms, modules and structures.**

(57) A composite preform or module comprises a filamentary reinforcement (16) deposited in a groove (12,44,46,32) pre-formed in a metal or ceramic foil (10,40,42). By depositing the filamentary reinforcement (16) in a groove (12,44,46,32) its position and distribution can be readily determined and held during consolidation of the preform. A plurality of preforms (modules) can be laid together to provide a described structure. The filamentary reinforcement (16) is held in place by, for example, a fugitive binder (36) and grooves 18 allow for the off-gassing of the binder during consolidation.

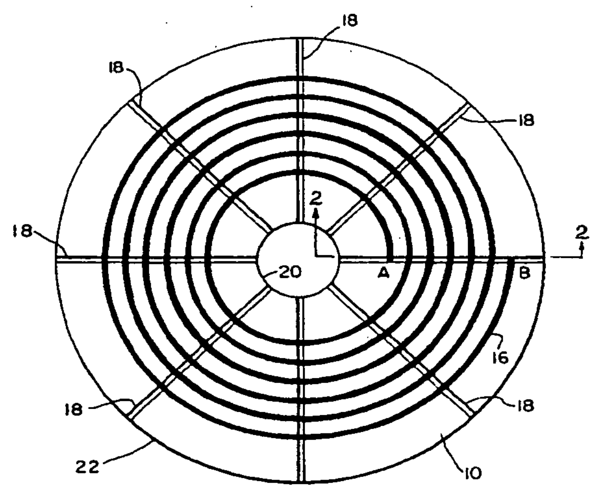

Fig.1.

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The invention is directed to composite preform modules, composite preforms, and processes for converting the modules and preforms into composite structures and composite materials.

For purposes of this discussion a composite preform is defined as a matrix material having distributed therein reinforcing filaments. The matrix material is configured to be consolidated with other preforms into a composite module, or composite structure.

A composite module is defined as a monolayer preform, or a multi-layer preform which is shaped and ready to be consolidated.

Composite materials and composite structures are in widespread use in aerospace structures, sporting goods, jet engines, and all manner of applications where materials having a high strength to weight ratio are desired.

There are several methods currently utilised for making fiber reinforced metal composite rings, disks, and shaped structures. One method of making reinforced rings or disks is to first make a unidirectional composite monolayer tape having a width equal to the maximum height of the desired rings. The strip is rolled into a ring having a desired inside and outside diameter. Alternatively, a ring is formed by co-winding a tape or dry fibre (held together with a cross weave of metal ribbon) with a strip of metal. The thus formed ring is then cosolidated using either internal or external radial pressure, that is, pressure is applied to the strip surface.

In this first method, as the fibres and metal are wound into an assembly of cylindrical layers, the coiled package requires the application of pressure in the radial direction so as to effectively flow the metal and consolidate the composite without distorting the fibre winding pattern. Applying pressure radially inwards or outwards, however, either buckles or breaks the fibre thereby distorting the ring and reducing the properties of the composite.

A second method requires the co-winding of a single filament and a metal ribbon into a grooved mandrel to form a continuous in-plane spiral of fibres separated by metal (see US-A-4697324). This assembly is then consolidated by applying pressure in the direction parallel to the axis of the shape thus overcoming the concern for fibre distortion, fibre breakage, or fibre buckling that result from radially consolidating the coiled package described in the first method.

Spirally winding single fibres together with a metal ribbon into a deep groove in a mandrel is difficult and can result in an irregular fibre/ribbon pattern that is not conducive to high material properties.

For improvement upon the second, a third method utilises a helical wound tape of filaments held together with a cross-weave of metallic ribbon and metallic foil of the same configuration. The two helical tapes are interleaved to form a helical assembly having turns of filaments alternating with turns of metallic foil. As in the second method, this assembly is then consolidated by applying pressure in the direction parallel to the axis of the shape.

This method utilises a woven tape containing a multitude of fibres that all terminate at one location causing an area of stress intensity. Experience has shown that the cross weave ribbon does not completely hold each fibre separate from its neighbour, resulting in possible unconsolidated void areas and resultant poor mechanical properties. Also, an irregular width tape is required to shape the profile of a disk. This is costly to produce and difficult to control during assembly.

Yet a fourth method utilises a spiral winding of fibres similar to that described in the second method. In this case, however, the fibres are held in position and spaced apart by a cross weave of metallic ribbons placed in the radial direction. This spirally wound preform is then interleaved with metal foil and consolidated by applying pressure in the axial direction.

It is an aim of the present invention to provide a metal foil composite preform which may be used to make metal matrix composite materials and structures.

It is another aim of the invention to provide a ceramic matrix composite preform which may be used to make ceramic matrix materials and structures.

It is an aim of the invention to provide a composite preform which can be consolidated axially without distorting the fibres.

It is another aim of the invention to provide a composite preform where the fibres will not terminate in a concentrated area.

It is yet another aim of the invention to provide a composite preform where a shaped disk can be made by varying the positioning of the fibres for each individual preform.

It is still another aim of the invention to provide a composite preform in the shape of a straight or curved ribbon that retains all of the advantages and improvements cited above.

It is a further aim of the invention to provide a process for making shaped structures by laying up composite preforms into a desired shape having predetermined properties and consolidating the preforms

A first aspect of the invention provides a composite preform comprising a foil having a groove therein, and a filamentary reinforcement positioned within the groove. Prerferably there is provided means for holding the reinforcement within the groove.

By positioning the filamentary reinforcement in a groove, the reinforcement can be readily located in the preform and distributed according to a desired pattern.

The foil material may be of metal or alloy, or of ceramic or other suitable matrix material. The grooves may be chem-milled.

The reinforcement may be held in place by a fugitive resin binder which will off-gas during consolidation, and grooves extending across the filament receiving grooves may be provided to facilitate the escape of the gas.

Unlike the previous described methods which were primarily suited for metal matrix construction, the present invention also lends itself to making ceramic composite preforms and modules and structures. The invention will be described, however, primarily in terms of a metal foil matrix.

A metal foil composite preform comprises a metal foil with a groove having a predetermined depth and width. A continuous length of fiber is placed in the groove. There is also provided off gassing means to permit gas to escape from the groove. The preform may take the shape of a ring or disk with the groove being an archimedean spiral. Alternatively the preform may be a ribbon with a number of grooves defined therein.

The invention also comprises a process for making a multi-layered composite structure which calls for superimposing a plurality of the metal foil composite preforms configured to a desired shape and consolidating the preforms under heat and pressure to form a fully dense composite material or structure.

The novel features that are considered characteristic of the invention, both as to its organisation and method of operation, together with additional objects and advantages thereof, will be better understood from the following description of specific embodiments, when read in conjunction with the accompanying drawings, in which:

Figure 1 is a top view of a composite preform forming an embodiment of the invention, in the shape of a disk;

Figure 2 is a view taken along the line 2-2 of Figure 1;

Figure 3 is a schematic representation of a method of making a composite preform in the shape of a disk;

Figure 4 is an alternate way of constructing a composite disk using a split plate;

Figure 5 is a composite preform forming a second embodiment of the invention, in the form of straight ribbon;

Figure 6 is a representation of a partial cylindrical tube constructed by laying up ribbon preforms; and

Figure 7 shows a plurality of ring preforms positioned for consolidation.

In its most primitive form there is shown in Figures 1 and 2 a foil composite preform where a spirally wound preform is achieved by winding the fibre into grooves formed in a foil made from aluminium, titanium, aluminides, or any metal or alloy commonly used to make composite materials and structure.

As best seen in Figure 2, a disk 10 comprises a metal foil having a spiral groove 12 defined in one surface 14 of the foil, and a fibre reinforcement 16 is positioned within the groove. The disk 10 also contains a plurality of radially directed grooves 18 used for offgassing the preforms during consolidation.

The type of fibre reinforcement 16 is not critical. The fibre reinforcement 16 may be carbon, boron, silicon carbide, titanium diboride and the like. The form of the fibre reinforcement 16 may be in the form of a tow or a monofilament.

Currently and preferably a silicon carbide monofilament within a titanium foil is the preferred combination.

Referring to Figure 1 the groove 12 containing the fibre reinforcement 16 begins at a specified polar coordinate "A" and rotates through a number of complete 360 degrees revolutions. The spiral ends at a final polar coordinate "B" having the same angular position as the initial polar coordinate. Where one desires an archimedean spiral, a constant incremental radial increase per each 360 degrees revolution is structured.

Also included are a number of linear grooves 18 which extend radially outward from the inside diameter 20 of the disk 10 to the outside diameter 22. The linear radial grooves 18 allow for off gassing or removal of a fugitive resin binder 24 (see Figure 2) that is provided to temporarily hold the fibre within the groove before and during the consolidation process that will follow. The preferred fugitive binder is acrylic resin. Acrylic resin leaves no residue when it is vaporised. Other means of holding the fibre in place are a plasma sprayed overcoating or vacuum applied through holes in the face.

The spiral groove 12 provides a constant and equal radial spacing for a single continuous fibre 16 that is placed in the groove 12. The spiral groove geometry is such that it will maintain a radial spacing, determined by the groove design configuration, between consecutive revolutions at all points along the entire length of the in-place spiral filament.

Referring to Figure 3 there is a schematic representation of one way to construct a preform in the shape of a washer. The fibre 16 is taken from a spool 26 and placed into the groove 12 where it is bonded by acrylic or other suitable bond - not shown. The disk 10 is slowly rotated in the direction of the arrow 28. The fibre 16 is fed into the groove 12 and under the rollers 27. The rollers maintain the fibre within the groove until the bond is applied.

Figure 4 shows an assembly formed from two thin foils 40 and 42 that have shallow groove configurations 44 and 46 that are mirror images of each other. This can be used with thin foil to provide higher fibre volume or foil thickness if needed.

Referring to Figure 7A there is shown a plurality of monolayered preforms 10 concentrically placed one on top of another. A foil 30 is placed over the top

preform 10. Figure 7A illustrates a way of producing a varied cross sectional arrangement of reinforcirig fibres with a predetermined fibre stacking order. The assembly of preforms 10 is ready for consolidation.

Figure 7B allows spacing variations of fibre within a composite structure for consolidation condensation.

Figure 5 shows a ribbon preform where all of the grooves 32 are straight and parallel to one another. Each of the grooves 32 contains a fibre reinforcement 16. A transverse groove 34 is provided for off gassing during consolidation. The fibres are kept in place by a thin layer of a fugitive binder 36 such as acrylic.

Figure 6 shows a partial representation of a cylindrical tube formed by wrapping layers of ribbon preforms on a mandrel. The composite structure, in this case a composite tube, is formed by consolidating the layers of ribbon.

The preforms described above provide a number of benefits that include: 1) varying the size of the disc internal diameter and thickness dimensions as necessary to comply with a final part design, 2) varying the groove depth and width to comply with final part design criteria, and 3) varying the constant incremental radial increase per revolution to comply with the stress or strain requirements of the final part design.

The various features and advantages of the invention are thought to be clear from the foregoing description. Various other features and advantages not specifically enumerated will undoubtedly occur to those versed in the art, as will many variations and modifications of the preferred embodiments illustrated, all of which may be achieved without departing from the spirit and scope of the invention.

Claims

1. A composite preform comprising
   a foil (10,40,42) having a groove (12,44,46,32) therein, and
   a filamentary reinforcement (16) positioned within the groove (12,44,46,32).

2. A composite preform as claimed in claim 1, characterised in that the groove (12,44,46,32) is dimensionally equal in depth and width.

3. A composite preform as claimed in claim 1 or 2, characterised by means (24,36) for holding the reinforcement within the groove (12,44,46,32).

4. A composite preform as claimed in claim 1,2 or 3, characterised in that off gassing means (18) is provided for removing gas from said groove.

5. A composite preform as claimed in any one of claims 1 to 4, characterised in that the filamentary reinforcement (16) is a continuous length.

6. A composite preform as claimed in any one of claims 1 to 5, characterised in that the groove (12,44,46,32) is in the shape of an archimedian spiral.

7. A composite preform as defined in any one of claims 1 to 6, characterised in that the holding means comprises a fugitive binder (24,36) to hold said filamentary reinforcement (16) in the groove (12, 44, 46, 32).

8. A composite preform comprising
   a plurality of foils (10,40,42) configured into a predetermined structural shape, each of said foils (10,40,42) having a groove (18) defined therein, the groove containing a filamentary reinforcement, and off-gassing means (18).

9. A metal foil composite comprising
   a foil (10,40,42) having a groove (12,44,46,32) defined therein,
   a filamentary reinforcement (16) positioned in the groove,
   means (36) for holding the filamentary reinforcement (16) in the groove,
   and off-gassing means (18) for enabling gas to escape from said groove.

10. A composite as claimed in claim 9, characterised in that the groove (18) is in the form of an archimedian spiral.

11. A composite as claimed in claim 9 or 10, characterised in that the filamentary reinforcement (16) is a continuous monofilament.

12. A composite as claimed in any one of claims 9 to 11, characterised in that the preform is of titanium, the grooves (12,44,46,32,18) are chem-milled, and the filamentary reinforcement (16) is of silicon carbide and is held in place by an acrylic fugitive binder.

13. A process for making a multi-layered composite structure, comprising
    superimposing a plurality of metal foil composite preforms (10) configured to the shape of the composite structure;
    and consolidating the preforms under heat and pressure to a fully dense composite.

14. A process as claimed in claim 13, characterised in that each preform comprises a metal foil (10,40,42) having filamentary reinforcement (16) situated within a groove (12,44,46) defined in said foil (10,40,42).

15. A process as claimed in claim 13 or 14, charac-

terised in that off-gassing means (18) is provided to permit gas to escape from the preforms during consolidation.

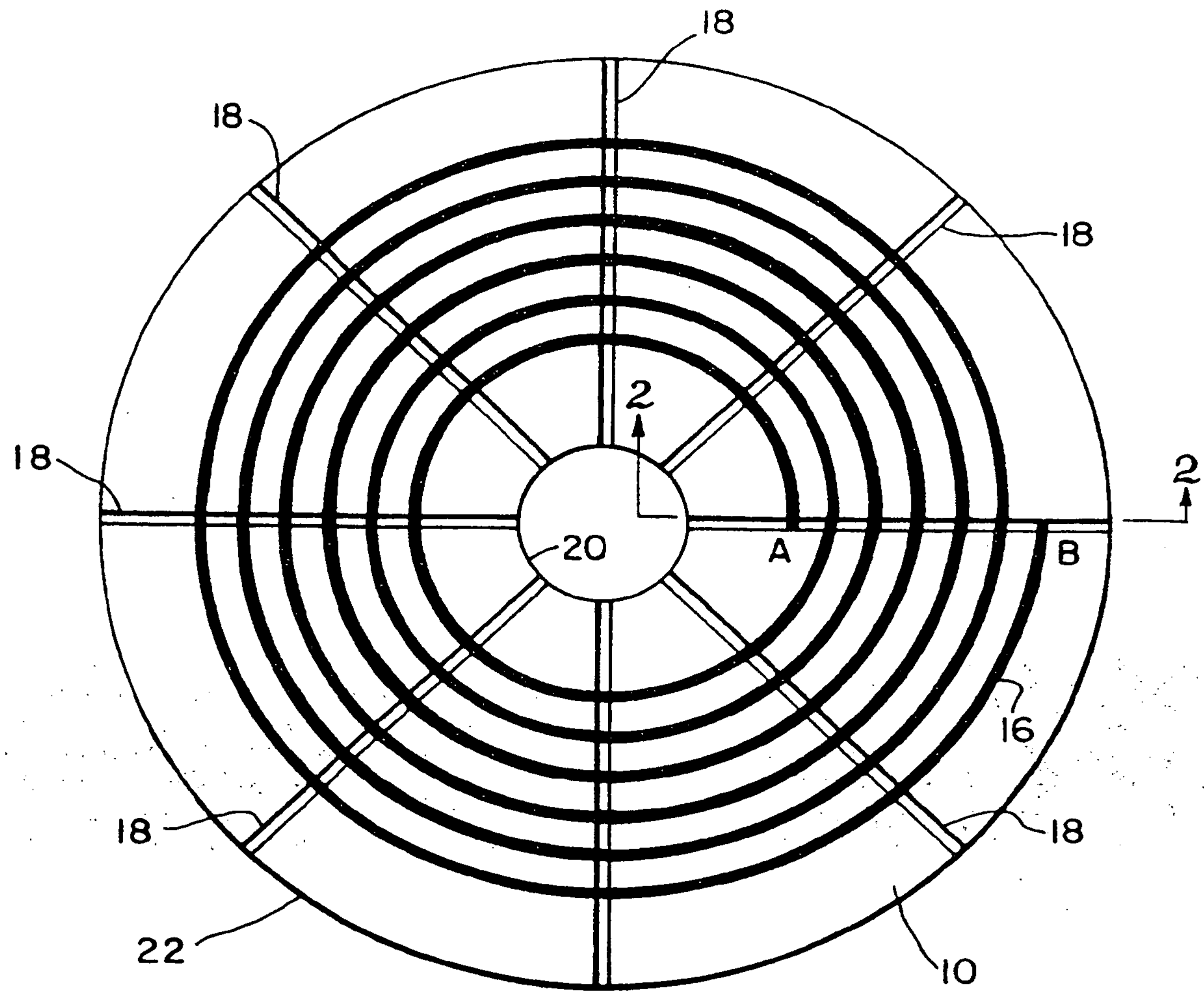

Fig.1.

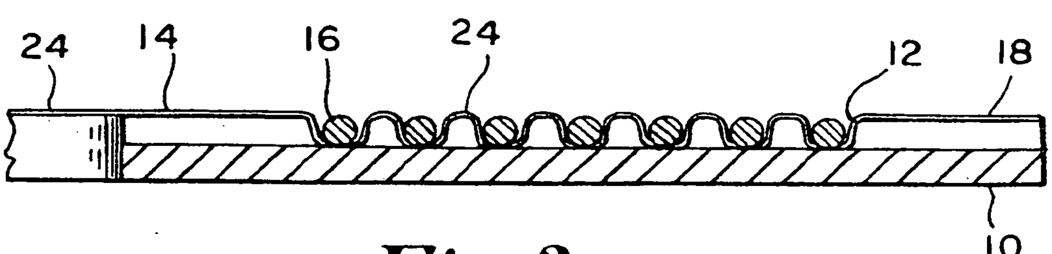

Fig.2.

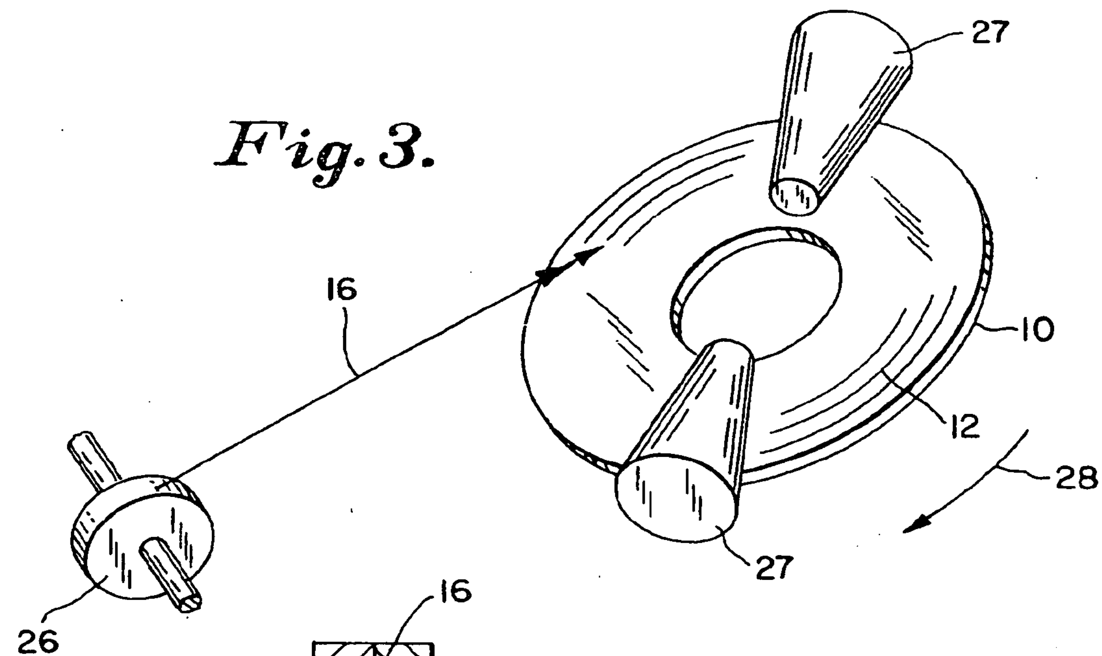

Fig. 3.

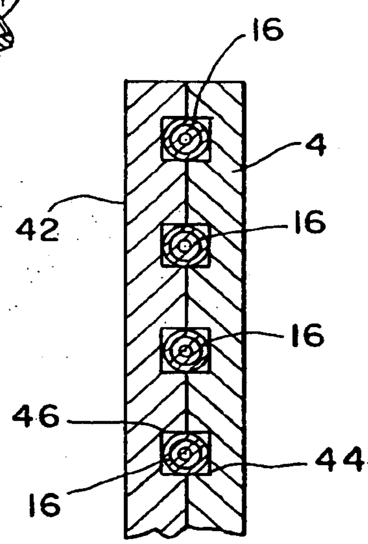

Fig. 4.

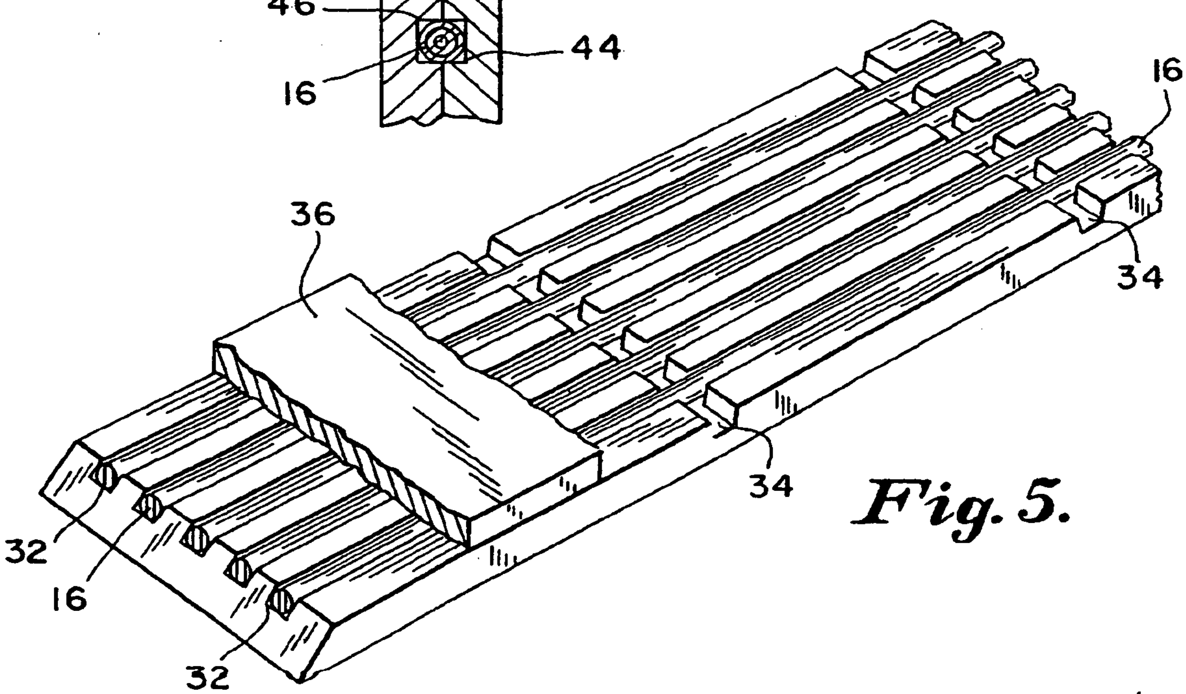

Fig. 5.

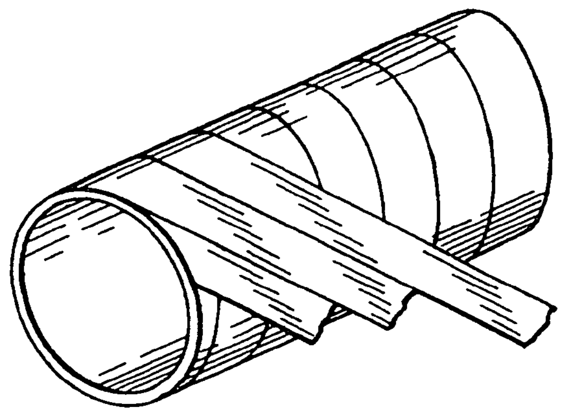

Fig. 6.

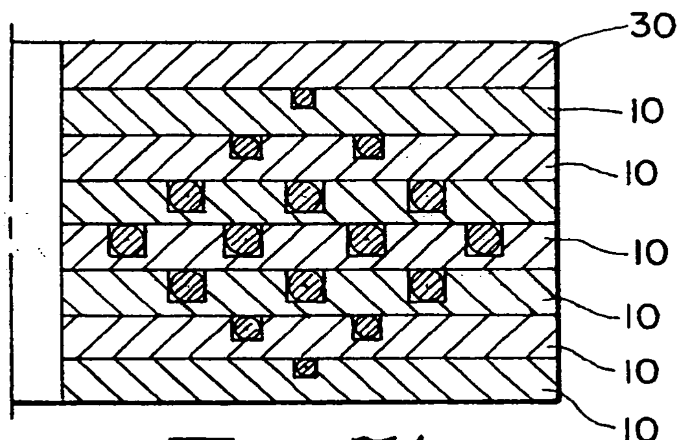

Fig. 7A.

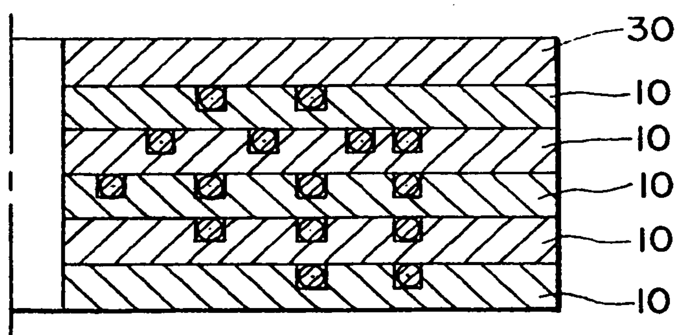

Fig. 7B.